Anchoring and Black Swans: Reconsidering Risk Aversion and the Future of Commercial Space

"…the important thing is not to stop questioning…"

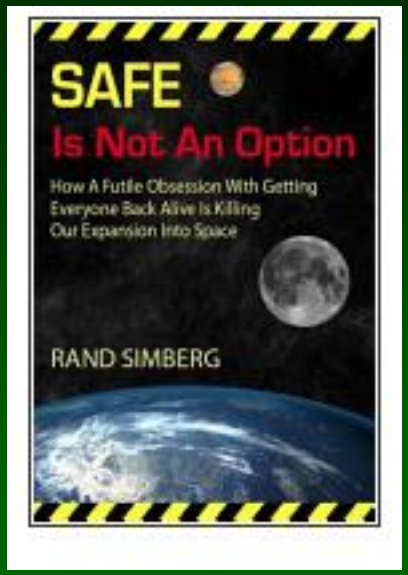
(Einstein & later, X-Files)

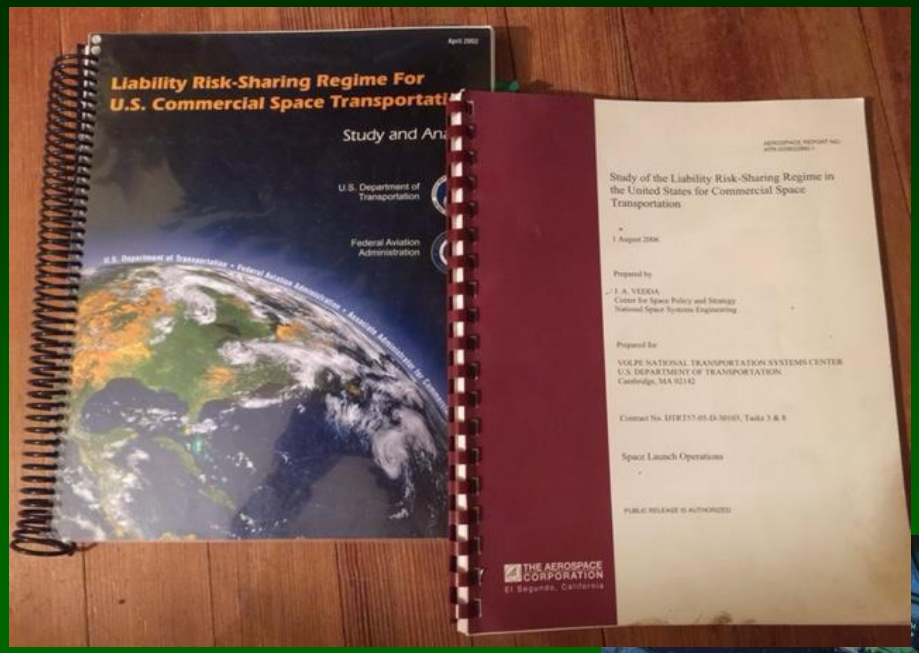
Experts' Workshop

22 March 2016

Washington, DC

RESOURCES FOR THE FUTURE


SAFE
Is Not An Option
How A Futile Obsession With Getting Everyone Back Alive Is Killing Our Expansion Into Space
RAND SIMBERG


Liability Risk-Sharing Regime For U.S. Commercial Space Transportati
Study and An
U.S. Department of Transportation
Federal Aviation Administration
Study of the Liability Risk-Sharing Regime in the United States for Commercial Space Transportation
1 August 2006
Prepared by
J. A. VEDDA
Center for Space Policy and Strategy
National Space Systems Engineering
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VOLPE NATIONAL TRANSPORTATION SYSTEMS CENTER
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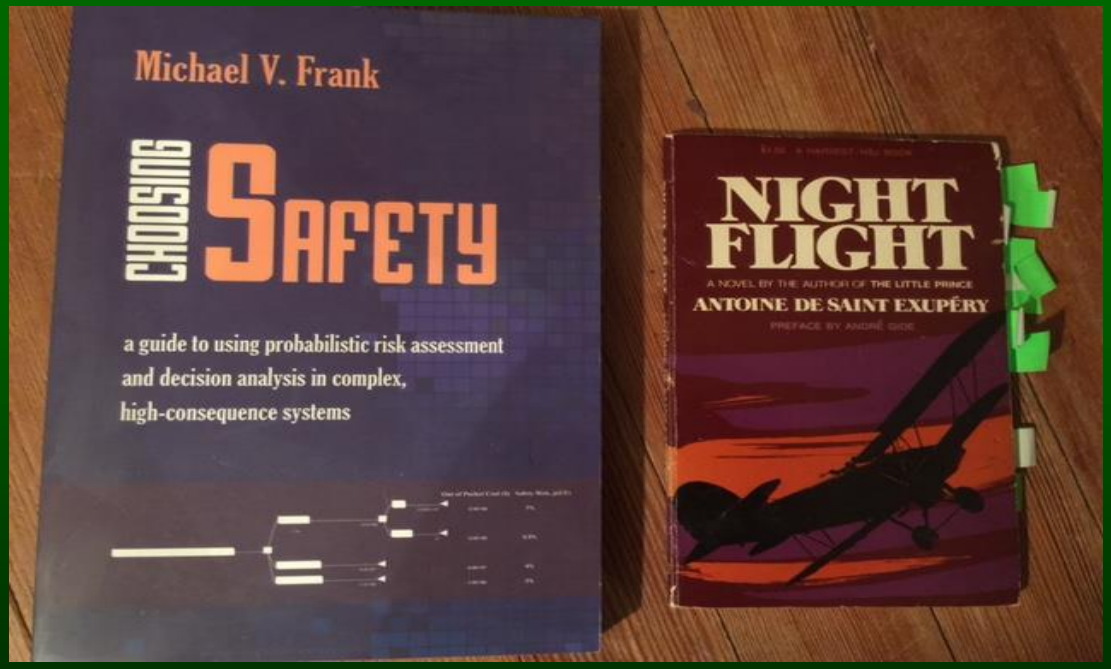
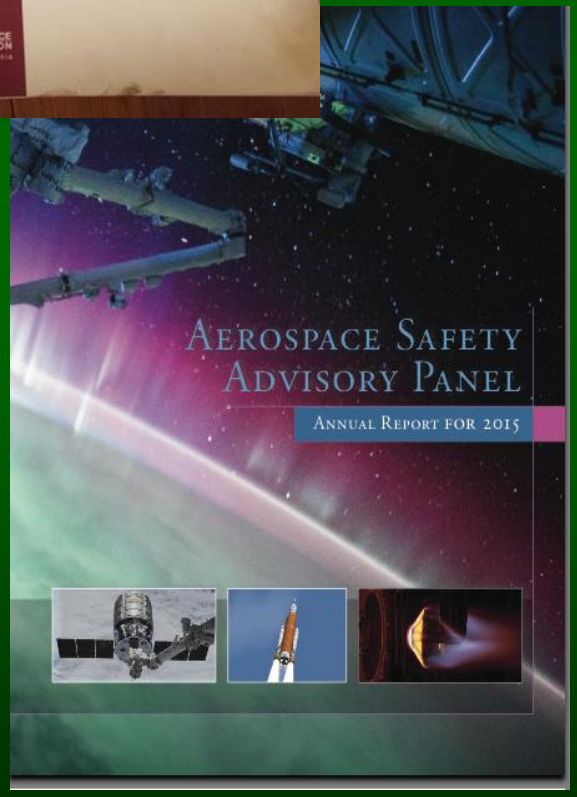

Michael V. Frank
CHOOSING SAFETY
a guide to using probabilistic risk assessment and decision analysis in complex, high-consequence systems
NIGHT FLIGHT
A NOVEL BY THE AUTHOR OF THE LITTLE PRINCE
ANTOINE DE SAINT EXUPÉRY
PREFACE BY ANDRÉ GIDE


AEROSPACE SAFETY ADVISORY PANEL
ANNUAL REPORT FOR 2015

Project Overview and Objectives

- Examine public & government attitudes towards risks to humans in space
  - to inform future space safety guidelines
  - how this risk is communicated to the public by decisionmakers
- Consider whether "anchoring" of public expectations may be influencing acceptable risk, including perception of "black swan" events
- Discussion topics:
  - Government "risk conservatism"
  - Risk analogs
  - Other agencies and metrics ("Value of statistical life")
  - Public perception
  - Policy implications
  - Continuing to ask the question

Discussion Topics

- Government “risk conservatism” ? (Molly / All)
- Risk analogs (Jim / All)
- Public perception (Katrina / All)
  - The public perception as reflected in “value of statistical life”
  - The public perception as reflected in polling
- Policy implications (All)
- Continuing to ask the question (All)

Government "Risk Conservatism"?

- Biases in cost and benefit balancing:
  - Safety, health, and environmental regulation: may go forward even if costs larger than benefits
  - Political costs of a mistake may exceed benefits of avoiding costs that are largely invisible

- Rate on US Treasury bills relatively lower than other financial instruments: demand-driven, perceived to have no default risk

- Government self insures: services and infrastructure assumed replaceable, costs to public not explicit

- Yet:
  - Government as agent & guardian of public trust and wealth

  - Government as appropriate agent to invest in long-term high-risk investments

Government "Risk Conservatism" contd

- Ambiguity aversion (dislike of gaps in information regarding probabilities or outcomes): distinct from risk aversion but can be manifested as risk conservatism (Onculer)
- "Virgin" (black swan??) and "experienced" risks ((Kousky, Pratt, and Zeckhauser in Michel-Kerjan and Slovic, adapted from figure 11.1))

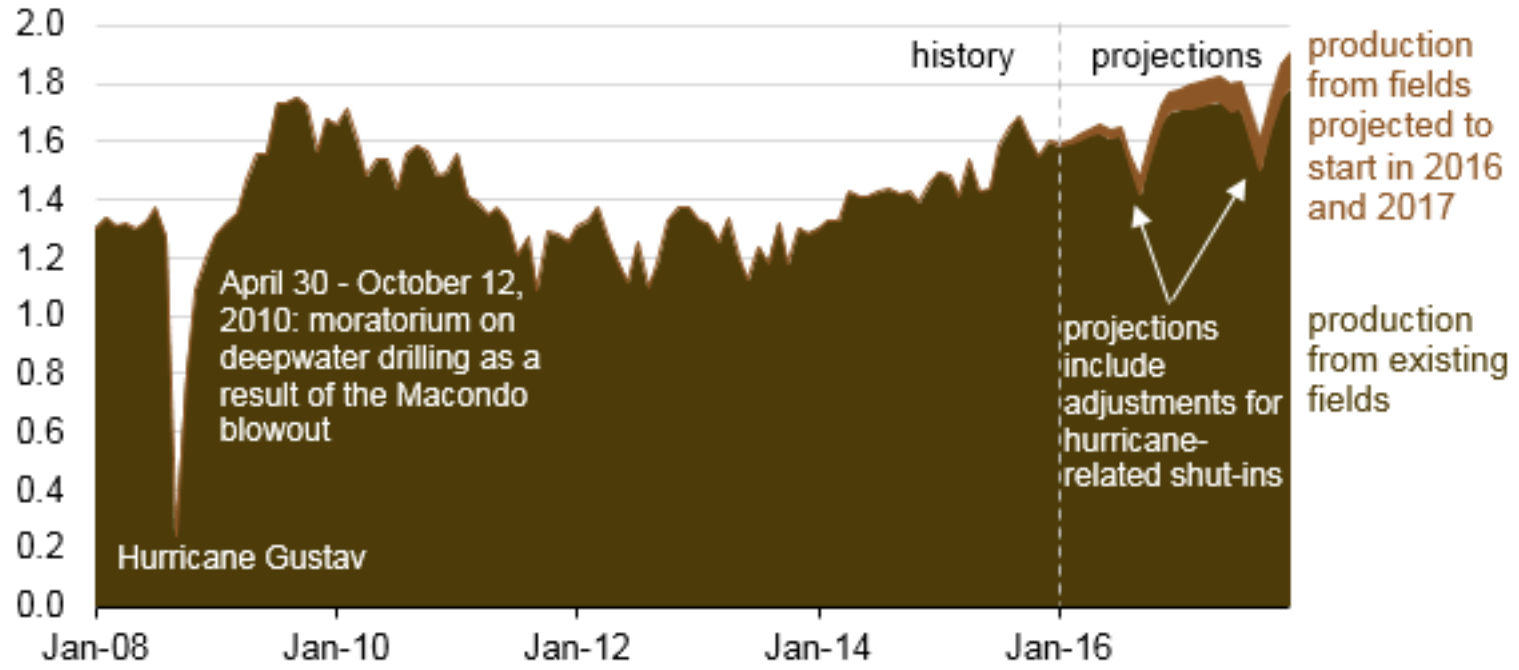
	Unrecognized	Recognized
No Occurrences	Virgin risks	Contemplated risks
Past Occurrences	Neglected risks	Experienced risks

The Cost of Various Risk-Reducing Regulations Per Life Saved

Regulation	Year	Agency	Initial Annual Risk	Annual Lives Saved	Cost Per Life Saved (thousands of 1984 dollars)
Oil and Gas well service	1983	OSHA-S	1.1 in 10^3	50.000	100
Underground Construction	1983	OSHA-S	1.6 in 10^3	8.100	300
Crane suspended personnel platform	1984	OSHA-S	1.8 in 10^3	5.000	900
Concrete and masonry construction	1985	OSHA-S	1.4 in 10^5	6.500	1,400
Grain dust	1984	OSHA-S	2.1 in 10^4	4.000	2,800
Benzene	1985	OSHA-H	8.8 in 10^4	3.800	17,100
Asbestos	1986	EPA	2.9 in 10^5	10.000	104,200
Land disposal	1986	EPA	1.1 in 10^6	2.520	3,500,000
EDB	1983	OSHA-H	2.5 in 10^4	.002	15,600
Formaldehyde	1985	OSHA-H	6.8 in 10^7	.010	72,000

Annual deaths per exposed population. An exposed population of 103 is 1,000, 104 is 10,000 etc.
Source: John F. Morrall, III, "A Review of the Record." *Regulation*, November/December 1986, pp.25-34: table 4, p.30
Adopted from Weimer, figure 9-13

Monthly oil production from U.S. federal Gulf of Mexico (2010-17)
million barrels per day



Source: U.S. Energy Information Administration, *Short-Term Energy Outlook*, February 2016

National Academies presentation for the Decadal Survey for Earth Science and Applications, extract from slide deck, Mike Freilich, 19 January 2016

We note that the space science community has a very high professional opportunity cost in failures

- Government “risk conservatism”
- Risk analogs
- Public perception
- Policy implications
- Continuing to ask the question

Analogs – see handout material

- Role of government
  - Funding of enabling infrastructure
  - Funding of the activity itself
  - Ownership & operation of the assets (e.g., hardware, labor force)
- Risk attitudes
  - Public
  - Policy documents
  - Agents themselves (e.g., the astronaut, pilot)
- US and other countries

Commercial aviation
High-risk scientific research
Recreation/adventure markets

Examples going forward – emerging “analogs”

- Nuclear power/ safety and waste management (science has advanced; public concerns remain)
- Geoengineering (public concerns remain; policy lagging)
- Autonomous (self-driving) cars (policy lagging)
- Cybersecurity (technology, policy lagging)

Analogs: Caveats

- Small numbers situation, statistically and in public perception?
- Misalignment between public and decisionmakers in willingness to accept risk?
- Misalignment in attitudes towards risk in public cases compared with private cases?
- Looking towards the future, any past evidence of success in changing risk-averse position of officials, other stakeholders?

- Government “risk conservatism”
- Risk analogs
- Public perception
  - The public perception as reflected in “value of statistical life”
  - The public perception as reflected in polling
- Policy implications
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Value of a Statistical Life/Value of Risk Reduction

- **Based on how much people spend to reduce small amounts of risk in their daily lives; not value of lost earnings or an individual life. Ex:** "If one person would pay $50 to reduce mortality risk by 1/100,000, then 100,000 would spend $5 million to avoid one expected death."
- **Routinely used in benefit and cost analyses; long history with regulatory programs**
- **Measured primarily through wage differentials associated with occupational risk (revealed preference)**
- **Differs with income, other important factors**
- **Official OMB guidance $1-10 million**

Figure 4. Summary of International Differences in "Value of a Statistical Life"		
Country	Median VSL (millions, 2000 US$)	GDP per capita
US[1]	7 (4-9)	25,602 (1974)*; 40,946 (2000)
UK[1] **n=5**	15.175 (4.2-74.1)	21,900 (1982); 36,597 (2001)
Canada[1] **n=6**	5.3 (2.2-21.7)	28,254 (1989); 28,710 (1995)
Australia[1] **n=2**	9.7	24,602 (1991); 28,017 (1997)
Austria[1] **n=1**	5.2	25,964 (1986)
Switzerland[1] **n=1**	7.45 n/a	53,092 (2001)
Japan[1] **n=1**	9.7 n/a	32,112 (1991)
South Korea[1] **n=1**	0.8 n/a	10,567 (1993)
Taiwan[1] **n=2**	0.55 (0.2-0.9)	11,650 (1997)*, 12,561 (1999)*
Hong Kong[1] **n=1**	1.7 n/a	20,444 (1998)

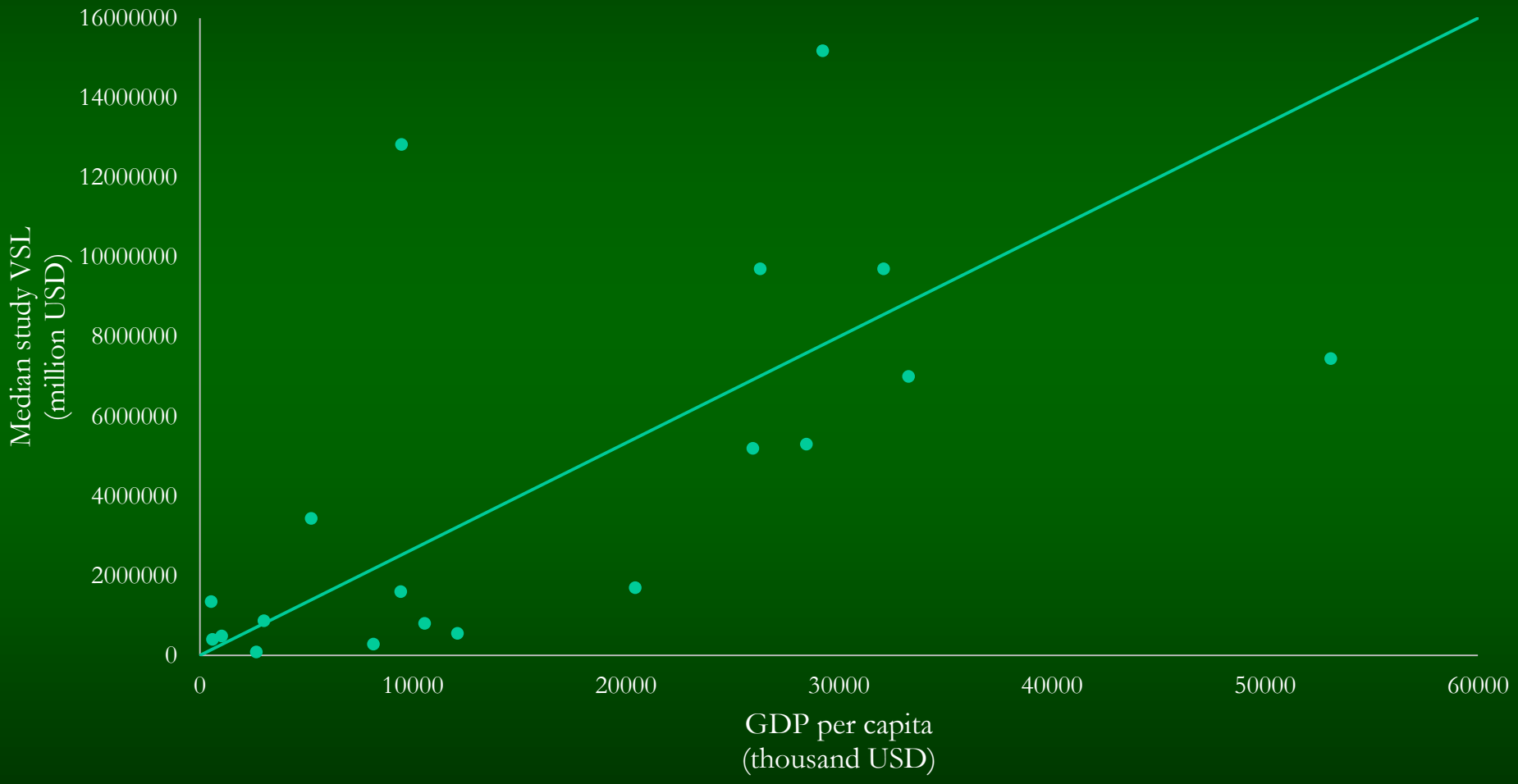
Notes : When number of studies varied by country, calculated median value for country estimate. When study presented VSL as range, calculated average for study estimate. Ranges given may reflect bounds from different studies.

References: [1]Viscusi and Aldy (2003); [2]Yaduma et al. (2012); [3]Guo and Hammitt (2008); [4]Hammitt and Zhou (2006); [5]Qin et al. (2013); [6]Parada-Contzen et al. (2012); [7]Vassanadumrongdee and Matsuoka (2005); [8]Gibson et al. (2007); [9]Giegiczny (2008); [10]Cameron et al. (2010); [11]Hammitt and Ibarraran (2006); [12]Ortiz et al. (2009)

Per capita GDP Sources: All in 2005 USD from World Bank, except * in 2010 USD from USDA Economic Research Service

Figure 4. Summary of International Differences in "Value of a Statistical Life" con't.		
Country	Median VSL (millions, 2000 US$)	GDP per capita
India[1] **n=3**	1.35 (1.0-4.1)	493 (1996), 503 (1997), 572 (2000), 589 (2001)
Nigeria[2] **n=1**	0.489 n/a	1,034 (2012)
China[3, 4, 5] **n=3**	0.08215 (0.0294-.277808)	1,950 (2006); 2,416 (2008); 3,619 (2013)
Chile[6] **n=1**	12.8265* (lower when not corrected for endogeneity)	9,478 (2012)
Thailand[7, 8] **n=2**	0.87 (0.25-1.48)	2,874 (2005); 3,158 (2007)
Poland[9] **n=1**	1.6 (0.79-2.41)	9,446 (2008)
Cambodia[10] **n=1**	0.4 n/a	605 (2010)
Mexico[11] **n=1**	0.28 (0.235-0.325)	8,163 (2006)
Brazil[12] **n=1**	3.435 (0.77-6.1)	5,239 (2009)

Relationship between GDP per capita and VSL estimates from literature



US Government Agency VSL

Figure 5. Summary of US Executive Agency Differences in Value of a Statistical Life ($2012)	
Agency	VSL
Environmental Protection Agency (EPA)	$9.7 million
Food and Drug Administration (FDA)	$8.06 million
Centers for Medicare & Medicaid Services (CMS)	$5 million
Department of Transportation (DOT)	$9.1 million ($5.2-$12.9 million)*
National Highway Traffic Safety Administration (NHTSA) Federal Motor Carrier Safety Administration (FMCSA)	$6.1 million
Federal Communications Commission	$9.1 million
Pipeline and Hazardous Materials Safety Administration	$6.2 million
OMB Circular A-4 Guidance	$1-$10 million
Source: Viscusi (2014) *Official VSL range adopted by agency	

US Government Agency VSL cont.

Figure 5. Summary of US Executive Agency Differences in Value of a Statistical Life ($2012)	
Agency	VSL
Mining Safety and Health Administration (MSHA)	$8.7 million
Federal Aviation Administration (FAA)	$6.2 million
Occupation Safety and Health Administration (OSHA)	$8.9 million
Food Safety and Inspection Service	$6.8 million
Department of Homeland Security (DHS)	$6.1 million
Transportation Security Administration (TSA)	$6.1 million
Federal Railroad Administration	$6.3 million
U.S. Customs and Border Protection	$3.2, $6.4 million
Consumer Product Safety Commission	$5.4 million

VSL in Our Context

- The problem of small numbers
- Spacefarers drawn from a different population distribution
- Differences among countries likely relevant

- Government “risk conservatism”
- Risk analogs
- Public perception
  - The public perception as reflected in “value of statistical life”
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- Policy implications
- Continuing to ask the question

Return to flight

- STS 26 (September 1988) 32 mos after Challenger loss (January 1986)
  - Rogers Commission Report (June 1986); US House Cte on Science and Technology (October 1986)

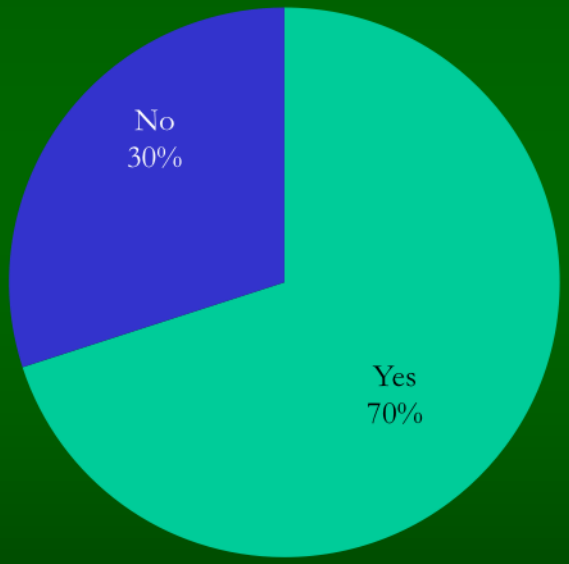
- STS 114 (July 2005) 29 mos after Columbia loss (February 2003)
  - Columbia Accident Investigation Board Report (August 2003); NASA's Columbia Crew Survival Investigation Report (Spacecraft Crew Survival Integrated Investigation Team (SCSIIT)) (December 2008)
  - Delayed ISS

- Booking for Virgin Galactic **Space Travel Rises To Previous Levels:**

Bloomberg News (3/15, Kamel) reports that bookings from budding space tourists looking to fly with Virgin Galactic "have recovered almost to the level seen before the fatal breakup of its SpaceShipTwo rocket plane in October 2014." Speaking on Tuesday at a conference organized by the UN's ICAO and the UN Office for Outer Space Affairs in Abu Dhabi, Virgin Galactic CEO George Whitesides said that following the deadly accident, about 25 of the company's 700 fee-paying clients opted out of the program, noting, "We had a little dip right after the accident, but honestly we're almost all the way back now." Whitesides also "said the company is getting closer to the first flight, while declining to disclose the schedule."

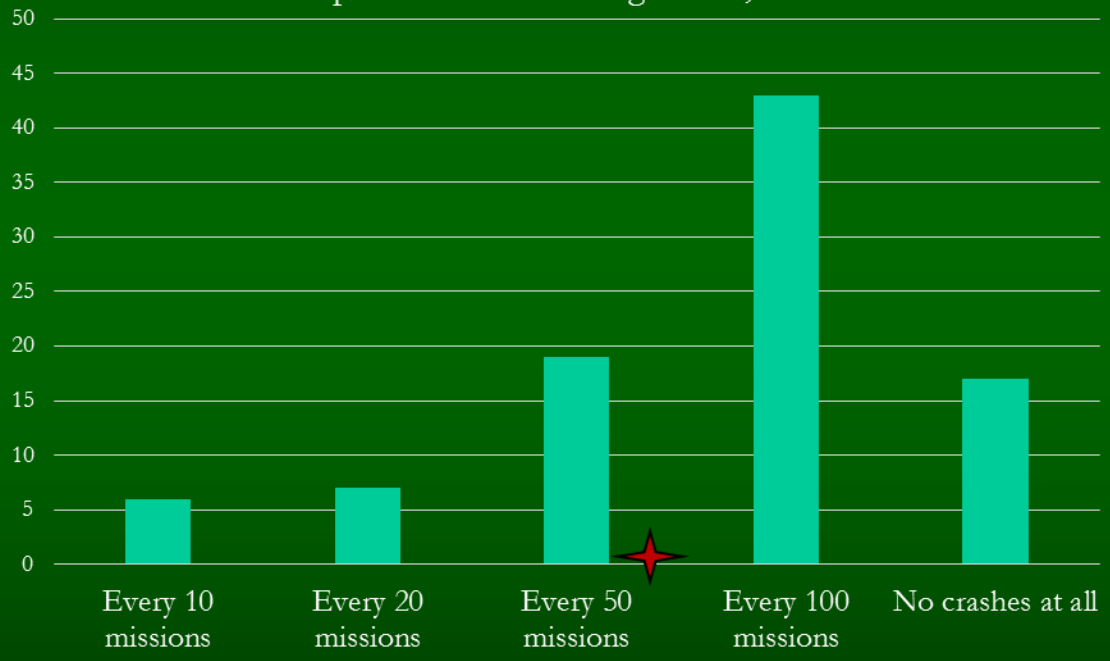
Willingness to Accept Risk to Astronauts

Do the benefits of space exploration outweigh the risk to astronauts?
Gallup Poll conducted July 2004



N=1000
SE=3%
16 day poll
Commissioned by Space Foundation

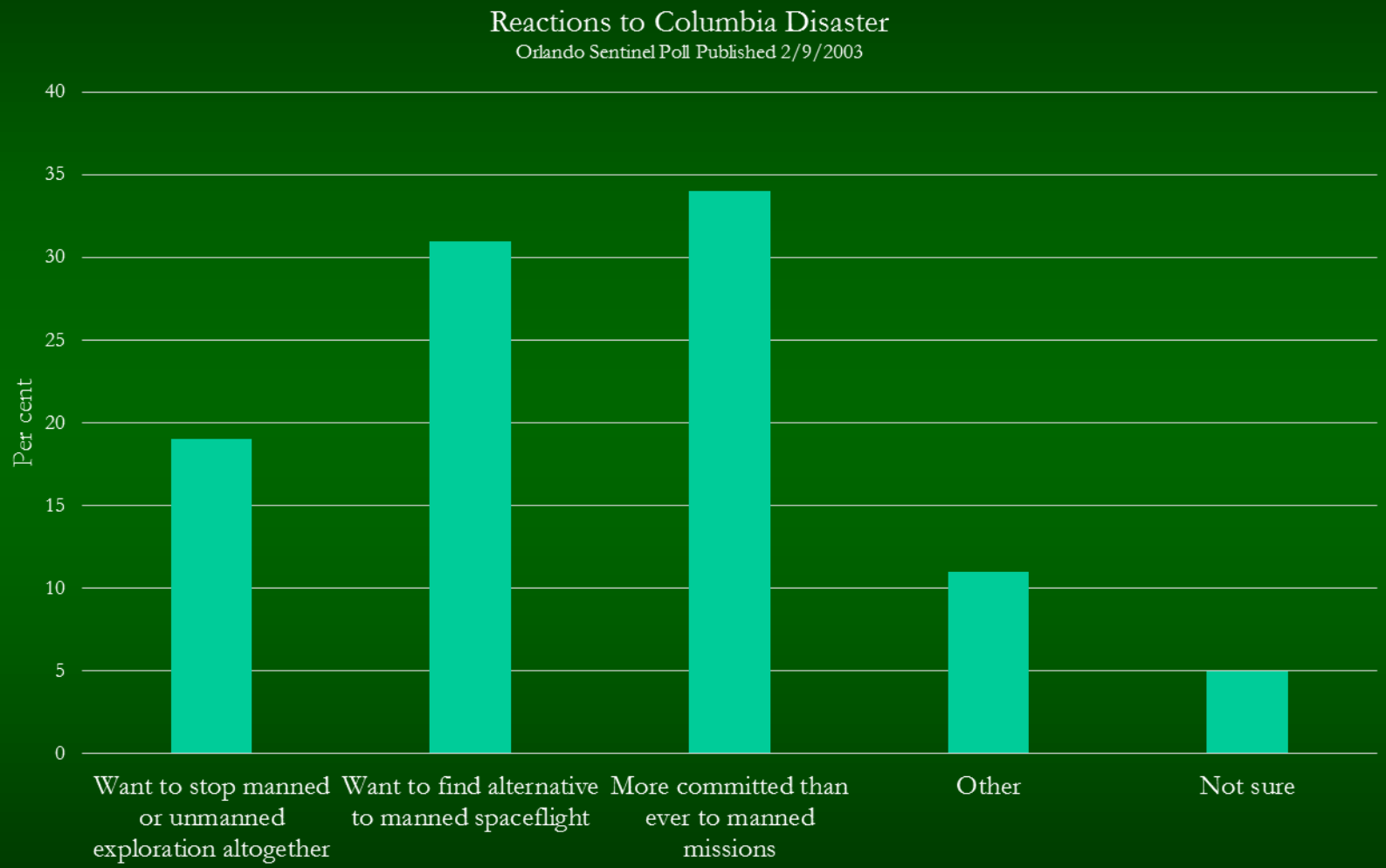
Acceptable price to pay to advance space exploration goals – frequency of fatal crashes
Gallup Poll conducted August 4-6, 2003



= observed rate of fatal crashes, every 57 missions

N=1003
SE=3%
3 day poll

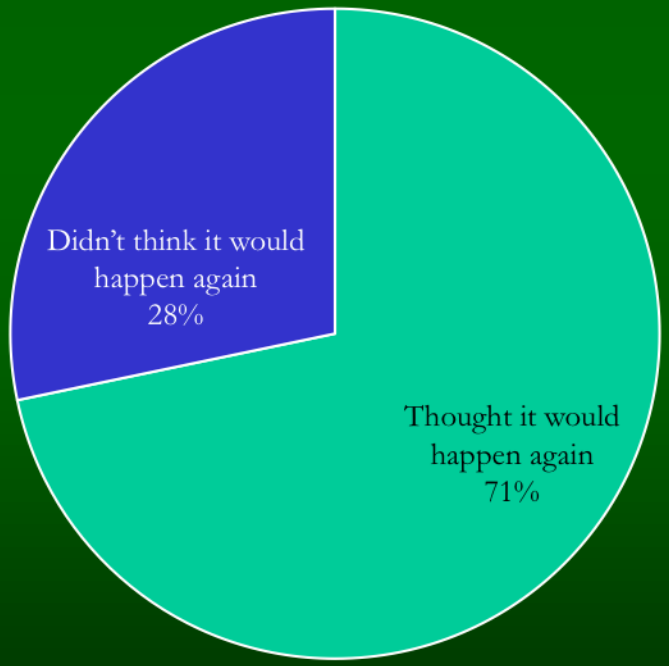
Support after disasters



N=1000
SE=3%
3 day poll
Conducted by Ipsos Public Affairs

Expectations there will be more disasters

Which comes closer to your view: yesterday's tragedy was regrettable, but you thought something like this would happen again sooner or later, or yesterday's tragedy was regrettable and you didn't think something like this would ever happen again in your l



Findings about public attitudes

- Approach
  - Lexis Nexis 1964-2009, Gallup/Pew polls, general searches for polling data.
  - Lexis Nexis search terms: space shuttle, survey/opinion/canvass; spaceflight, risk, NASA, Orbital Sciences, Virgin Galactic
- Key findings
  - Higher levels of support and WTA risk after disaster events
  - Higher support for manned spaceflight and desire to travel in space personally among: men, young people, higher income, higher education
  - General baseline willingness to accept risks to astronauts (?)
  - Belief that disasters will happen in future (?)
- Key caveats
  - Non-uniform polling: different questions, phrasing, methods
  - Phrasing of question affects results, especially with fatality/risk perception
  - Most polling occurred after major disasters or events

Public Perspectives: after loss of Challenger (Jan 1986)

- 1986: “Should US concentrate on unmanned missions or also include manned missions” – support for manned [67%]
- 1986: [66%] felt (in varying degrees) that manned space travel should not be abandoned in favor of unmanned crafts; what to do with shuttle program: [64%] continue as planned, [7%] continue but don’t allow civilians on board, [16%] shuttle phased out in favor of unmanned satellites, [7%] eliminate entire shuttle space program, [6%] don’t know
- Sep 1986: [89%] thought shuttle flights should be resumed despite risks associated with manned flight; [85%] thought US should replace Challenger; [13%] said manned space flight program should not continue; 22% approve flights with astronauts only when it is absolutely necessary but never flights with civilians.

Public Perspectives: after loss of Columbia (Feb 2003)

- 2003: Should US concentrate on unmanned missions or also include manned missions – support for manned [73%]
- Feb 2003: [34%] Columbia disaster makes public more committed than ever to manned missions, [31%] makes public want to find an alternative to manned spaceflight; [19%] makes public want to stop manned or unmanned exploration altogether; [11%] other; [5%] unsure
- Feb 2003: confidence in NASA's ability to avoid similar accidents in future – expressed confidence that another shuttle loss could be avoided [82%]
- Feb 2003: Did you expect second fatal shuttle incident – [71%] not unexpected, [28%] surprised another shuttle had been lost in their lifetime
- Feb 2003: [71%] shuttle program is worth the risk to the astronauts
- Feb 2003: [65%] benefits of human space travel outweigh the risks, [25%] space travel is too dangerous for manned spacecraft and benefits not worth the risk, [10%] not sure/other

Public Perspectives post- Columbia, contd

- Aug 2003: How likely do you think NASA is to repeat the types of mistakes that doomed Columbia and Challenger and experience another accident? [51%] likely to repeat mistakes, [47%] not likely to repeat mistakes, [2%] not sure.
- If the space-shuttle program gets under way again on a similar schedule, how likely is it that in the next 7 years or less there will be another catastrophic disaster like Columbia or Challenger? [68%] likely to happen, [28%] not likely to happen, [4%] not sure
- Aug 2005: How confident are you that NASA can make the space shuttle safe to fly on future missions – [41%] very confident, [42%] somewhat confident, [13%] not too confident, [3%] not at all confident, [1%] no opinion
- Aug 2005: Amount of confidence that NASA can prevent disaster similar to Columbia/Challenger: [20%] great deal of confidence, [56%] fair amount of confidence

- Government “risk conservatism”
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Policy implications

Space uniqueness or space exceptionalism?

-- Opportunity cost of failure has been high
-- Small sample
-- High public/international visibility yet public risk tolerance?
-- Conflation of many objectives of a space program
-- Infrastructure cost vs VSL (US GAO/NASA estimate of shuttle orbiter replacement cost, as of 1993: $1.8 B)
-- As move towards greater private activity and informed consent and risk-sharing, any key differences?

Looking towards the future, any past evidence of success in changing risk-averse position of decisionmakers?

Terrorism Risk Insurance, Price Anderson Nuclear Industries Indemnity Act, and the Liability Risk-sharing Regime in the US & other countries for commercial space transportation

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In conclusion

“…the important thing is not to stop questioning…”

(Einstein & later, X-Files)